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SNOW AND ICE RESEARCH IN CANADA, 1988

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MANAGEMENT PERSPECTIVE

The establishment of a national or international focus for hydrology at the National Hydrology Research Institute means that staff there accept positions with national and international bodies. One appropriate activity is that of Canadian national correspondent for one of the commissions of the International Association of Hydrological Sciences. Simon Ommanney is the National Correspondent for the International Commission on Snow and Ice. One of his roles is to prepare an annual report on snow and ice research in Canada for publication in the Canadian Geophysical Bulletin. This report is that for 1988.

PERSPECTIVE DE GESTION

ABSTRACT

This report briefly outlines research undertaken in Canada in 1988 that falls within the general subject areas covered by the International Commission on Snow and Ice (ICSI) of the International Association for Hydrological Sciences. It deals with the subject matter according to the subject areas used by ICSI: Seasonal Snow Cover and Avalanches; Glaciers and Ice Sheets; River, Lake and Sea Ice; and, Ice as a Material (including ice in the atmosphere, in the ground, and extra-terrestrial ice). After a general introduction, activities are discussed according to a regional framevork covering the Atlantic Provinces, Quebec, Ontario, the Prairies, British Columbia and the Territories. The report has been prepared by the Canadian ICSI Correspondent for publication in the Canadian Geophysical Bulletin.

RÉSUMÉ

SNOW AND ICE RESEARCH IN CANADA, 1988

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1.0. INTRODUCTION

The International Commission on Snow and Ice (ICSI), which developed from the International Commission on Glaciers created in 1894, considers its domain to be all aspects of snow and ice, viz. glaciology. Four Divisions exist to guide work in the major areas of the science: Seasonal Snow Cover and Avalanches; Glaciers and Ice Sheets; River, Lake and Sea Ice; and, Ice as a Material. Last year's account on snow and ice research in Canada, was written under the constraint of relevance to hydrology. Fortunately, there has now been a recognition that this prevents a true picture of ICSI-related activities in Canada. Therefore, the present report will deal with each of the major ICSI divisions in turn.

The narrative is based on a variety of submitted individual reports supplemented extensively by reference to papers published in 1988. These are not appended here, but should be retrievable through WATDOC. Author's affiliations, when known, are given in abbreviated form after their names. These are usually universities or institutes.

2.0. SEASONAL SNOW COVER AND AVALANCHES

There were no major meetings in 1988 to provide a strong focus for Canadian research in this area. The few papers published in the scientific literature, the proceedings of the Eastern and Western Snow Conference and the 7th Northern Research Basins Symposium reflect the generally low level of activity in research on the seasonal snow cover and avalanches. Prowse (NHRI), in collaboration with Landine, Granger and Gray (Sask), has reported on the evaluation of five models for predicting snowmelt run-off in the Arctic. It appears unlikely that any will give reliable predictions without extensive modification. The HYDROTEL model (Québec) is being investigated as the "base"

for the project which will likely derive its field data from a site along the Norman Wells/Zama pipeline route, near the headwaters of the Petitot River. Rango has used data from the Illecillewaet River in assessing the development of an operational snowmelt/run-off forecast model based on remote sensing. Cavadias (McGill) and Morin (UQUAQ) have considered confidence levels for the verification criteria of the WMO intercomparison of models. On the remote-sensing side, Wankiewicz (NHRI) has been studying microwave brightness differences in Manitoba and relating these to temperature and water equivalent. Goodison, Metcalfe and others (AES) are continuing their work on the development of new snow-depth sensors and the comparison of measurement techniques. Perla (NHRI) has investigated the water content of snow and developed a capacitive cell for its measurement. He has also proposed refinements to the International Snow Classification. Unfortunately, changing priorities at NHRI led to the closing of the snow laboratory at Sunshine. In the popular press, some concerns were expressed about the use of chemicals and bacteria for the enhancement of snow making. Regionally the situation is as follows.

2.1. Atlantic Provinces

Banfield (MUN) reported on variations in winter snow accumulation, spring run-off and temperature for the Grand Lake catchment in Newfoundland. Routine snow surveys are still being undertaken in New Brunswick in connection with the Saint John River basin study.

2.2. Quebec

The Lac Laflamme area, in the forêt Montmorency, has been the focus of a major environmental study by Jones (INRS-Eau), Roberge (Laval), Berraja (UQUAM) and others. Recent reports deal with snowmelt modelling and the loss of nitrate from the snowpack. Pesant (AgCan) and Granberg (Sherbrooke) are studying soil erosion processes during snowmelt at the Lennoxville Experimental Farm. The McGill University station at Schefferville contributed a thesis on snow and ground thermal regime by Desrochers. Continuing work there by Granberg with Nadeau and Kulkarni (McGill) includes an assessment of the radiation balance. To the northwest, along the Hudson Bay coast, Morin and Payette (Laval) have reported the influence of snow patches on gelifluction. In a study related to caribou migrations, Dubois and others (Sherbrooke) are mapping the snowcover

of northern Quebec for 1980-1986 from NOAA images.

2.3. Ontario

The Chalk River area has provided studies by Barry (AECL), Craig (NHRI), Price (Toronto) and others on snowmelt and the chemical composition of meltwater. In Peterborough, Buttle and Xu (Trent) have studied urban influences on snowmelt run-off.

2.4. Prairie Provinces

Saskatoon remains the focus of snow research in this area. At the university, Granger, Gray, Pomeroy and others have looked at the energy-budget, evaporation and aspects of blowing snow. At NHRI, Nicholaichuk continues his research on the influence of stubble height on snow trapping, finding a benefit of 15-22 $/ha in dry years and 5-7 $/ha in years of average rainfall. In Manitoba, McGinn and Cherneski (Brandon) are studying the characteristics of snowmelt peak flows along the Escarpment. In Alberta, Swanson (Alta. Forest Ser.) reports on the effect of in situ evaporation on the perceived snow distribution in partially clear-cut forests, following up on a long-standing study of the effects of forest clearings.

2.5. British Columbia

No work has been reported for this province in 1988. The BC Ministry of Environment and Parks continues to publish regular snow survey bulletins.

2.6. Territories

Snow characteristics along caribou trails and in feeding areas have been reported by Duquette (Western) for Yukon. For this area, DIAND continues to publish regular snow survey bulletins. In Mackenzie, Marsh (NHRI) is studying the movement of the wetting front through the snowpack and the creation of flow fingers that channel the meltwater and influence energy transfer at the snow/soil interface. In Franklin, the hydrology of a snow bank in a continuous permafrost zone on Melville Island is the subject of a thesis by Young (Toronto). Roulet and Woo (McMaster) are continuing similar studies near Resolute. Drinkwater (JPL), Crocker (SPRI), Scharfen (Colorado) and others have made observations about the snow cover on sea ice, an area that has been much neglected in the past. Information on the chemical composition

of the Arctic Ocean snow cover may come from samples collected by the Polar Bridge Expedition.

2.7. Avalanches

The NRC avalanche group in British Columbia under Schaerer (IRC) continued field observations and the development of models for the prediction of speed, impact pressures and run-out distances of avalanches, as well as of snow glide. Various *in situ* tests are being assessed, including the applicability of a shovel shear test. Jamieson (Calgary) completed a thesis on the *in situ* tensile strength of snow in relation to slab avalanches.

3.0. GLACIERS AND ICE SHEETS

Glacier research in Canada during 1988 continued at about the same level as in the previous year. A major external effort has been the Snow and Ice Hydrology Project in Pakistan, funded by IDRC and directed by scientists at Wilfrid Laurier University, in collaboration with a number of other Canadian universities.

Two books published in 1988 contain some general information on Canadian glaciers. Flood Geomorphology, published by Wiley, in the chapters by Church and Costa, describes a number of glacier-induced floods in glacierized regions of Canada. Osborn and Luckman, in a report on Holocene Glacier Fluctuations, published in Quaternary Science Reviews, summarise recent information on the glacier history of the Rockies. Wood (US Congress) has looked at the situation more globally and his report on glacier trends for the 1960s to the 1980s includes most significant Canadian data.

3.1. High Arctic

On Ellesmere Island, Koerner and his colleagues from the GSC have continued their work on Agassiz ice Cap. Bulk melting of ice at several depths in the 123-m borehole provided samples for pollen analysis of Sangamon, Wisconsin and Holocene ice. Core data was re-analysed in terms of the age of basal ice in Greenland and the effect of the massive discharge of melt water from the Laurentide ice sheet 18 000 to 10 000 years ago. Pollen concentrations were measured to identify the source regions of aerosols and/or the mode of origin of the ice. Synoptic analyses were made to determine the effect of the

eruption of Tambora on the regional climate. Analysis of core data has led to several papers on likely flow conditions around Devon Island by Klassen, Fisher, Reeh (GSC) and Paterson.

The mass balances of Melville south, Meighen, Agassiz north and Devon northwest ice caps was measured for 1986/1987. Haythornthwaite (GSC) described topographic changes on Meighen Ice Cap and Blatter and Kappenberg (ETH) mass balance and thermal results from Laika Glacier, obtained during the North Water Project.

Further south, Souchez and others (Brussels) have reported on a continuing analysis of data from Bylot Island, Hooke and others (Minnesota) on a revised interpretation of the rheological contrast between Pleistocene and Holocene ice of the Barnes Ice Cap, and Stolle (McMaster) on a model of its flow.

Interest in the implications for offshore structures of ice island movement has led to a number of studies of the Ward Hunt Ice Shelf and its neighbouring ice shelves by Jeffries (Alaska), Lemmen (Alberta), Frederking (IRC) and others.

3.2. Yukon Territory

Yukon remains the focus for much of the Canadian glacier work with Clarke (UBC), Holdsworth (NHRI) and Johnson (Ottawa) being the main players. Clarke is still anticipating a surge of Trapridge Glacier in several years. The glacier has been resurveyed, its water system measured and subglacial material sampled. Direct in situ measurements of till rheology were obtained using electrolytic tilt sensors in the deforming glacier substrate.

On Mount Logan, Holdsworth, in addition to the striking correlation between the annual net mass balance time series (1900-1980) and the areal mean of the November-March precipitation from the Steppe region of the central U.S.S.R., has found teleconnections between the Mount Logan time series and series for the Canadian Prairies and Japan between 1900 and 1987. Isotopic seasons are generally phase lagged with respect to calendar seasons. They appear to be correlated with SSTs, ocean heat transfer curves and the position of the Aleutian Low rather than with air temperature or the temperature difference between the ocean surface and the core site. An improved, shallow, ice-borehole logging system has been developed.

Johnson summarised some of the information on rock glaciers in Yukon and, with Lacasse, reported on those in the Dalton and Kluane Ranges.

Blumenstengel and Harris (Calgary) have observed an active lobate rock glacier in the Slims River valley. Sedimentation and drainage characteristics of an ice-dammed lake associated with the Kaskawulsh Glacier were reported by Kasper (Ottawa).

3.3. British Columbia

The NHRI mass balance programme in the Coast Mountains was contracted to UBC in 1988. Place and Helm Glaciers had negative balances in 1987 (-0.79, -0.85 m H_2O) and 1988 (-0.97, -0.15), while Sentinel continued to be anomalously positive (+0.15, +0.45). Ricker and Tupper observed the advance of the Overlord Glacier. Osborn and Karlstrom summarised the Holocene history of the Bugaboo Glacier.

3.4. Prairie Provinces

The only mass balance programme in the Rockies continues to be that at Peyto Glacier. Here, Holdsworth observed negative balances in both 1987 and 1988. Letréguilly (NHRI) has considered the relation between mass balance data here and in the Coast Mountain with meteorological data. Holdsworth has also been studying the winter hydrograph and recent history of the glacier; wood retrieved from the snout has been dated at 2900-3100 B.P. Munro (Toronto) is continuing an energy-balance study here.

To the north, at the Athabasca, Dome and Boundary Glaciers, Luckman (Western), and Gardner and Jones (Waterloo) have been studying moraines and ice-marginal debris deposits.

4.0. RIVER, LAKE AND SEA ICE

As there are so many similarities in the work being done regionally on sea ice, it will be considered separately, after the discussion about river and lake ice.

The Fifth Workshop on the Hydraulics of River Ice, held in Winnipeg in June, 1988 brought together much of the recent Canadian river-ice work and some was included in the Ninth International Symposium on Ice, organised by the International Association for Hydraulic Research in Sapporo. This latter meeting also contained a lot of sea-ice work.

A number of methodological studies were reported in the last year.

Pelletier (WSC) reviewed techniques and uncertainties related to the Water Survey of Canada winter streamflow measurements. Frazil modelling is discussed by Tsang (NWRI) in a number of papers. Other aspects of modelling have been considered by Arisz and others (UNB), Brunswick), Petryk (Tecsult Inc.) and Sarraf (Concordia). Prowse (NHRI) has described a method of measuring ice jam porosity and, with others, the use of a borehole jack for measuring ice strength.

4.1. Atlantic Provinces

In Newfoundland, Anderson (Acres International Ltd.) and others have reported on an ice-related flood of Harry's River. Accounts of similar floods in New Brunswick appear in the reports of Acres International, El-Jabi (Moncton), Humes and Dublin (DOE), mainly dealing with the Saint John River.

4.2. Quebec

Effects of ice ride-up along shorelines of the Gulf of St. Lawrence are reported by Murty (Rimouski) and Dionne (Laval). Ice jams on the Ruisseau du Sud have been the object of study by Bergeron and Roy (Montréal). The chemical influence of a lake ice cover was addressed by Doran (Queen's) in Schefferville and its effect on oxygen depletion by Choulik (Trent). In the Hudson Bay area, Lepage and d'Anglejan (McGill) and others have observed the effects on the ice cover of the Great Whale River plume and on sedimentation rates. In the Bay itself, Anderson (Nebraska), Dubois (Sherbrooke), Ingram (McGill), Murat (Montréal), Prinsenberg (BIO) and others have reported on atmospheric conditions, remote sensing, vertical mixing and the contribution of ice ridges to the freshwater content.

4.3 Ontario

The centre of river-ice work in Ontario is NWRI where Beltaos and Tsang have continued their work on ice jamming processes and modelling and frazil-ice studies. Part has related to the Thames River system. Most of the work on the Great Lakes and Niagara River has been done by U.S. scientists, particularly those associated with the Great Lakes Environmental Research Laboratory. Canpolar Inc. has tested a marine radar system for detecting ice near the hydro-electric intake ducts for a major hydro utility. The system can provide all-weather, day-night ice detection capability. Specialised

software was developed to separate moving and stationary ice on a colour monitor for use by operational personnel.

4.4. Prairie Provinces

A major centre of floating ice research is the National Hydrology Research Institute in Saskatoon. Although some programmes are being developed in the Prairies, its scientists are chiefly working in the Territories and New Brunswick. Beltaos (NWRI) has discussed ice jamming on the Nelson River in Manitoba. In Alberta, Andres (Alta. Res. Council) has continued his studies on the break-up of the Athabasca River at Fort McMurray.

4.5. Territories

In Yukon, Alford and Carmack (NHRI) published their observations on the ice cover of the Yukon River near Whitehorse in 1985/1986 and, with others, a paper on ice-covered Lake Laberge. Ice jams and the resulting damage at Dawson are discussed by McCreath (Klohn Leonoff Inc.) and others.

The most active river ice research appears to be that undertaken along the Mackenzie River. Flato, Stanley and Gerard (Alberta), Kriwoken, Prowse (NHRI), Watson (Trent) and others have worked on the Liard and Mackenzie Rivers, particularly in the vicinity of Fort Simpson. Prowse reports that during melt periods, river ice can experience significant changes in strength that partly determine the severity of break-up conditions, but in situ strength tests are relatively scarce. A borehole jack was used to determine changes in ice strength during an 18 day pre-break-up melt period and measurements were also made of the river-ice energy balance. Strength decreased by approximately 50% at a rate of 0.4 MPa/d. Although a porosity of 0.4 is commonly assumed in the case of break-up jams, there had been no field verification of this value. On April 29, 1983, ice jam porosity was calculated by comparing the volume of ice melted within the jam to measured changes in the total (ice and water) jam volume.

Parkinson and Holder (LaSalle Hydraulics Lab.) have discussed ice-jam development at Norman Wells; Gerard and Stanley (Alberta) that on the Hay River.

Further down river, Marsh and Bigras (NHRI) have monitored break-up in the Mackenzie Delta, N.W.T. from 1981 to 1987. The location of frequent ice jams in the Delta, as well as their formation, composition, and growth, and the

backwater build-up and flow diversion patterns which result have all been documented.

4.6. Sea Ice

The sea ice community is generally more active and has been served by more meetings: the Seventh International Offshore Mechanics and Arctic Engineering Symposium in Houston; the Sea-Ice Workshop/Symposium at C-CORE; the fall meeting of the AGU in San Francisco; and the IAHR meeting in Sapporo, mentioned above. Many of the regional studies of ice in the Arctic Ocean and the Beaufort Sea emanate from the United States. Sanderson has provided an excellent overview of much of the offshore ice work in his book on ice mechanics, published by Graham and Trotman.

Many of the methodological papers on sea ice are concerned with better thickness-measurement techniques. Rossiter reports that Canpolar Inc. has been working with Aerodat Limited to design a practical sea-ice thickness sensor for use from a helicopter. Trials were conducted in the Canadian Arctic in 1987 and off Cape Breton, N.S. Instrumar, Iizuka (Toronto) and others have also described ice thickness devices.

4.7. Atlantic Provinces

Of primary concern in the offshore area is the problem of icebergs passing from Davis Strait, through the Labrador Sea into the area of the Grand Banks and threatening offshore structures and shipping. This, as well as the movement of the seasonal sea-ice pack. Scientists at Memorial University, C-CORE, the Institute of Marine Dynamics, and the Bedford Institute of Oceanography have been involved in measuring and modelling ice movements, ice impacts and ice scour. Interactive studies have been reported by Bhat (Amoco), Duthinh (C-CORE), El-Tahan (MUN), Hamza (IMD) and others. Numerical modelling, satellite-tracked ice beacons, image analysis and marginal ice zone experiments are being used by researchers at the Bedford Institute of Oceanography to understand the contributions of the atmosphere and ocean to the motion, growth and decay of the floating sea ice off Labrador and Newfoundland. Sea-ice coupled models (M. Ikeda, C. Tang) are used to explain and predict the variability of the southern sea-ice extent for periods of days to tenths of years; as well as the study of specific physical processes occurring in the marginal ice zone such as ice-edge upwelling, oceanic mixed

layer development and ice-edge meanders due to current-topography interaction. Modelling results are checked against regional ice-drift data obtained from satellite-tracked ice beacons (I. Peterson, S. Prinsenberg), image analysis (I. Peterson) and detailed site-specific data (C. Tang). Beacons have and are being developed (G. Fowler, S. Prinsenberg) for real-time ice, air and water temperature profile data to determine the seasonal variability of ice growth and decay rates of the moving pack-ice and landfast ice (S. Prinsenberg, I. Peterson, S. Smith). Iceberg drift surveys have been used in dynamic iceberg drift models (S. Smith) to determine the oceanic and atmospheric drift contributions. Concern with the hazard to seabed installations from drifting icebergs has prompted studies by Bass, Clark and Woodworth-Lynas (C-CORE), Venkatesh (AES), El-Tahan (MUN), Gaskill (MUN), Lewis (BIO) and others.

A major remote-sensing development has been the Labrador Ice Margin Experiment (LIMEX) that anticipates the eventual acquisition of radar data from the Canadian RADARSAT. This, and the desire to improve ice forecasting capabilities, has prompted AES to upgrade the Ice Centre facilities in Ottawa and initiate the Ice Data Integration and Analysis System Project (IDIAS).

4.8. Territories

A major area of continuing interest is the Beaufort Sea and Arctic Ocean. While most remote-sensing studies still seem to originate outside Canada, Ramseier and others (York) are developing algorithms for sea ice parameters.

Industrial activity in the offshore area has led to concern over the interaction of ice and structures. Abdelnour (Arctec), Croasdale (Esso), Frederking (IRC), Jeffries (Alaska), Jordaan (MUN), Masterson (Geotech), Metge (Canatec), Parsons (IMD), Sayed (IRC), Stander (Laval), Timco (NRC Hydraulics) and others have all addressed various aspects of this problem. Dryer (MIT), Lewis and Denner (Science Applications Int.) have reported on ambient noise levels resulting from ice movement in the Arctic Ocean. Key and McLaren (Colorado) have described the under-ice topography.

The establishment of "Hobson's Ice Island" as a floating research platform by the Polar Continental Shelf Project represents a major commitment to future Arctic Ocean and ice research.

5.0. ICE AS A MATERIAL (including ice in the atmosphere, in the ground, and extra-terrestrial ice)

Atmospheric ice research in Canada appears to be quite limited. Riming on hydro lines and other inland surfaces has been described by Druez (UQUAC), McComber (École de Technologie Supérieure, Montréal), Gates and Lozowski (Alberta), List (Toronto) and others. Some of these investigators, together with Zakrzewski (Alberta) and others have also dealt with aspects of marine icing.

Work on the physical properties of ice is largely limited to the Division of Chemistry at NRC. There, Whalley and his colleagues have done work on order-disorder transformations, melting of Ice VIII at low pressure, elastic constants under pressure, energies of the phases of ice, structure of Ice IX, structure of Ice V, a second kind of Tyndall figure, inelastic neutron scattering by high-density and low-density amorphous ice, and melting of low-density amorphous ice.

Some mechanical studies have been done in connection with floating-ice properties by Blanchet, Frederking (IRC), Jordaan (MUN) and others.

The major Canadian research area in this division is that relating to permafrost and ground ice. A strong focus was provided by the Fifth International Conference on Permafrost in Trondheim at which many Canadian scientists presented papers. In addition, two books have provided a useful perspective on Canadian studies. French (Ottava) has described ancient and modern periglacial phenomena in a report of the IGU Commission on the Significance of Periglacial Phenomena. He joined several other Canadian authors as a contributor to Advances in Periglacial Hydrology, published by Wiley. It appears that studies have been undertaken in most of the permafrost regions of Canada during 1988. In addition, the joint Canada/France Ground Freezing Project, with Carleton University, continues to produce results.

5.1. Atlantic Provinces

Evans and Rogerson (MUN) have reported on a gelifluction lobe in the Nachvak Fiord area of Labrador.

5.2. Quebec

Granberg (Sherbrooke), Desrochers, Pollard and Kingsbury (McGill), Stoker (Carleton) and others continue to describe results from the extensive permafrost research programme carried out over the years from the McGill Subarctic Research Laboratory at Schefferville. Reports have dealt with snow cover/permafrost relationships, palsas, freeze-thaw, the active layer and modelling. Further north, around Ungava Bay, scientists from the Université de Montréal and Université Laval have been describing the periglacial environment, shoreline permafrost, methods of estimating active-layer thickness, regional factors in permafrost distribution, rock pingos and ice-wedge polygons.

5.3. Prairie Provinces

Work in Manitoba has been concentrated in the area of discontinuous permafrost around Churchill. Dyke (GSC) has studied permafrost aggradation, Hallivell and Rouse (McMaster) evaporative controls on ground temperatures, and Etkin and others (AES) a long-term monitoring programme.

In Alberta, the test facility in Calgary has been used by van Everdingen, Carlson and Nixon to study ice lensing and heave effects on chilled pipelines. NHRI has initiated studies at Mt. Watt where Craig reports that preliminary geophysical profiles suggest that electro-magnetic surveying is an excellent method for detecting permafrost here and could permit mapping of the lateral distribution of frozen ground at different times of the year. Along the Mackenzie Highway, a re-examination of occurrences of frozen ground by Kwong (NHRI) indicated a local northward retreat of the fringe permafrost zone by as much as 120 km in the past 25 years.

5.4. Territories

A variety of studies have been reported from Yukon. Ground-water aspects are dealt with by Michel (Carleton) and van Everdingen, while Harris (Calgary) has discussed moisture redistribution in the active layer and Lauriol (Ottawa) cryoplanation terraces in the north of the Territory. Along the coast, massive ground-ice deposits of the Coastal Plain and near Cape Sabine have been described by Harry (GSC), Pollard (McGill) and others. Underground ice in the Tsi-Tché-Han Cave is reported by Lauriol and Thibaudeau (Ottawa). Burn (UBC) has published several papers on work done at Mayo. These have included

observations of near-surface ground ice, ice-wedge development, water migration, thermal offset, thermokarst lakes and the influence of organic mats on the active layer.

In Mackenzie, many of the studies relate to operational concerns with existing facilities. Thus Dufour (Geocon Inc.), Lafleche (GSC) and others have been trying to investigate leakage through an earthfill dam at the Lupin Mine, near Contwoyto Lake. Lafleche has also used ground-probing radar to study gravel bed road failure near Rae. Woo (McMaster), in addition to a general report on the wetland run-off regime, has described an effort to model the effects of uranium mine tailings on permafrost. Impacts of the Norman Wells/Zama pipeline are being monitored by Burgess (GSC), Kershaw (Alberta), Hanna (Hardy BBT Ltd.), Patterson (Carleton) and others.

More general studies of the permafrost environment are being conducted along the Mackenzie River and in the Delta. These include the effects of forest fires on permafrost stability (Harry, GSC), the permafrost regime (Allen, GSC), ground ice (Dallimore, GSC; Fujino and Horiguchi, Hokkaido; Lewkowicz, Toronto; Rampton, GSC), pingos (Mackay, UBC), soil infiltration and snow melt (Marsh, NHRI) and mapping (Sinha, GSC).

To the northeast there have been a number of studies on the islands in the District of Franklin. Taylor (GSC) has described insights into palaeogeography provided by deep ground temperatures. Allan (Trent), Lewkowicz (Toronto), Rudberg (Gothenburg) and others have reported on periglacial features such as slumps and solifluction lobes on Axel Heiberg Island. Similar surface creep forms have been studied by Bennett (Ottawa?) on Melville Island, and French (Ottawa) and Harry (GSC) have dealt with ground ice and permafrost features on Banks Island. Finally, some geotechnical aspects of saline permafrost at Clyde River, Baffin Island have been addressed by Nixon (Hardy BBT Ltd.).

6.0. CONCLUSION

Overall, the situation with regard to snow and ice research in Canada has not changed much since 1987. The more immediate geotechnical needs, related to development in Canada's cold regions, continue to sustain a higher level of activity in the areas of sea ice and permafrost research than is found in the other areas of interest to the International Commission on Snow and Ice.